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METHOD FOR INCREASING THE CALORIFIC VALUE OF FRAGMENTED WOOD BIOMASS

METODA ZWIĘKSZENIA WARTOŚCI OPAŁOWEJ ROZDROBNIONEJ BIOMASY DRZEWNEJ

Abstract

The need for drying of fragmented wood biomass as a method of increasing the calorific value of this fuel was justified. The original design solution for fluidization apparatus, which allows effective drying of the analyzed material, was proposed.

Keywords: wood biomass, drying, fluidization, calorific value

Streszczenie

Uzasadniono potrzebę suszenia rozdrobnionej biomasy drzewnej jako sposobu zwiększania wartości opałowej tego paliwa. Zaproponowano oryginalne rozwiązanie konstrukcyjne aparatu fluidyzacyjnego umożliwiające efektywne suszenie analizowanego materiału.

Słowa kluczowe: biomasa drzewna, suszenie, fluidyzacja, wartość opałowa

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1. Introduction

Wood biomass (chopped logs, wood chips, sawdust, cuttings) is available in sufficient quantities in Poland and becomes a very desirable energy source, which is consistent with the guidelines of the European Union. The aims of the 3 x 20 energy-climate package, which was adopted in 2008, oblige the European countries to reduce CO_2 emissions by 20%, reduce energy consumption by 20% and generate 20% of energy from renewable sources. In Poland, the development of energy technologies, particularly renewable energy sources (biomass) is delayed compared to other countries in the European Union [1]. So far small amounts of energy from renewable sources have been produced in our country (renewable energy was about 3.8% of the total energy sold to final customers in 2006) [2].

Woody biomass may be the perfect substitute for fossil fuels. It can be obtained from trees coming from pruning forests, orchards and green areas, as well as from energy crops.

The principles for the evaluation of biomass energy are the same as in the case of traditional solid and liquid fuels. The most important criteria are: the calorific value, moisture content, ash and sulphur content, specific melting temperature of ash, volatile matter content and grain size [3]. The biggest advantage of biomass is a zero balance of carbon dioxide (CO_2) released during biomass burning, and also lower emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_x) and carbon monoxide (CO) than those for fossil fuels. A disadvantage of biomass is its high and variable moisture content, which depends on the nature and duration of seasoning and low energy density per unit volume resulting in difficulties in its distribution and use. In addition, the very low density of biomass affects the cost of transport and storage. Therefore, biomass is the most common product manufactured, processed and consumed locally, for example, in municipalities.

The moisture content in biomass is closely related to the calorific value. The biomass obtained from both energy plantations and seasonal pruning can be used for combustion in boilers. However, the green biomass should be dried to increase its calorific value. It would make the combustion process more economically and energetically attractive. The calorific value of solid biofuels varies from 6–8 MJ/kg for biofuels with the humidity of 50–60% (fresh biomass) to 15–17 MJ/kg for air-dried biofuels with the humidity of 10–20% and up to about 19 MJ/kg for dried biofuels [4].

Therefore, an important step in the manufacture and processing of wood biomass for energy purposes is drying of the harvested product. Drying in a fluid system is characterized by favourable technical and economic indicators [5] and ensures that the desired quality of products is received.

The subject of this paper is to search for a method to ensure the efficient fluidized bed drying conditions of the crushed wood biomass to increase the calorific value of the fuel.

2. Characteristics of wood biomass

Biomass is the third largest in the world, natural source of energy. According to the definition of the European Union, biomass means the biodegradable fraction of wastes, agricultural industry (including plant and animal substances), forestry and related industries products, as well as the biodegradable fraction of industrial and municipal waste (Directive 2001/77/EU). Its resources can be stored and used as needed. The transport and storage do not involve such threats as those posed to the storage and transportation of crude oil. The use of wood biomass from forests reduces the risk of fire. Until recently, wood was a basic energy source. Currently, there is a lot of unused wood waste from various industrial sectors, e.g. residue constructional wood, wood trimmed to size or the waste material which does not meet the standards of semi-finished products, which constitutes 50% of processed wood [6]. Use of this waste for energy purposes can have huge significance in many industries and beyond. Furthermore, on about 20% of the area of our country the standards for concentrations of heavy metals in the soil were exceeded and plants grown there can be used for industrial purposes only. Therefore, these areas can be used for the cultivation of energy crops.

Due to the diversity of shape and the source of biomass wastes, the following types of waste biomass can be distinguished:

– Wood pieces – the residue (about 2%) of constructional wood, trimmed to size, or waste from the production of trimmed-to-size semi-finished products (e.g. friezes), or material not meeting the standards of semi-finished products (provides up to 50% of processed wood), its calorific value is 1911–1922 MJ/ kg, humidity – 20–30%, contains minimal amounts of bark.

– Sawdust – represents about 10% of wood processed in sawmills; sawdust is also a by-product of machine cutting, milling etc. in plants of more advanced wood processing, sawdust moisture content is varied and ranges from 6–10% to 45–65% for the sawdust from recently felled trees.

– Wood shavings – a wood-product similar to sawdust generated during cutting and milling; shavings have low humidity (5–15%).

– Woodchips – chipped wood in the form of 5–50 mm long cuttings of irregular shape, produced during the first cutting of trees, tops and other residues after felling, during the processing of logs in sawmills, on plantations of fast-growing willow, from waste wood in large plants processing wood; the calorific value of wood chips is 6–16 MJ/kg, humidity of 20–60%,

– Bark – energetically valuable waste from the timber industry, representing from 10 to 15% of harvested wood; its calorific value is 18.5–20 MJ/kg, humidity of 55–65%,

– Enriched fuel: briquette (a cylinder or a cube, formed of dry fragmented wood like sawdust, wood shavings or chips, pressed under high pressure without the addition of adhesive substances, energetic value: 19–21 GJ/t; moisture content: 6–8%) and pellets (made from wood waste – mostly from sawdust and shavings – a few inches long with a diameter of 6–25mm, energetic value of 5–17.5 MJ/kg, moisture content of 7–12%).

It should be noted that more and more attention is paid to enriching the solid biomass through the process of granulation (pelletization). Pellets are the solid fuel from biomass convenient for use in households, industry and district heating plants. Pellets are one of the cheapest fuels on the market. They are usually made of willow woodchips. Before pressing, wood chips are being dried to the moisture content of about 15%. In relation to the fuel oil heat unit costs are lower by half. Compared to other fuel costs, they are lower by about 30%. The granules are resistant to auto-ignition and natural decay. Easiness of loading the pellets to furnaces or boilers and a small amount of ash after combustion make such devices almost maintenance-free. Pellets occupy 10–30 times less space than fresh material, so their use decreases the costs of storage and transport [7–10]. The high moisture content in biomass also affects the costs of delivery. Biomass is often delivered for combustion from distant regions of the country. Transport costs are higher because of the water content, which makes the biomass even heavier. It is worth creating a mobile apparatus for drying in order to carry out the drying process at the production site of biomass. In this way transport costs would be lowered, decay would be limited, and storage would be easier.

Table 1 shows the selected properties of biomass due to its type and shape.

Table 1

Properties of solid biofuels [8, 11]

Biofuel	Moisture [%]	Calorific value [MJ/kg]	Density [kg/m^3]	Ash content [% d.w.]
Wood chips	20-60	6-16	150-400	0.6-1.5
Pellet	7-12	16.5-17.5	650-700	0.4-1.0
Yellow straw	10-20	14,3	90-165	4.0
Gray straw	10-20	15.2	90-165	3.0
Wood pieces	20-30	11-22	380-640	0.6-1.5
Bark	55-65	18.5-20	250-350	1-3

Figure 1 shows the comparison of the calorific value for different types of biomass

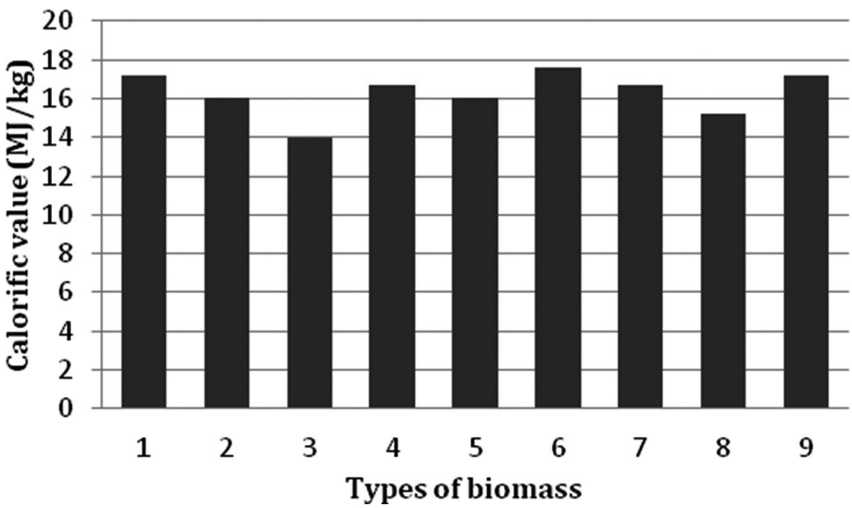

Fig. 1. Comparison of calorific value for different types of biomass:
1 – wheat straw, 2 – barley straw, 3 – rape straw, 4 – maize straw, 5 – wood chips,
6 – pellet, 7 – briquette, 8 – straw briquettes, 9 – grain oats [10]

Rys. 1. Porównanie wartości opałowej różnych rodzajów biomasy:
1 – słoma pszenna, 2 – słoma jęczmienna, 3 – słoma rzepakowa, 4 – słoma kukurydziana,
5 – zrębki, 6 – pelety, 7 – brykiet drzewny, 8 – brykiety ze słomy, 9 – ziarno owsa oplewione [10]

One of the major criteria for the assessment of biomass energy is the calorific value, closely related to the moisture content in wood. The water content depends on the species and the „age of" wood and varies between 20 to 60%. The calorific value is the amount of heat emitted during combustion per unit mass or unit volume of fuel; the combustion is full and complete, assuming that water vapour in the exhaust gas is not condensed, despite the fact that the gases have reached the starting temperature of the fuel [8]. The calorific value of wood also depends on its composition. Higher resin and lignin content in wood increases its calorific value. The content of lignin and resins is also dependent on a tree species and its „age". Lignifications processes intensify with a tree's age, so the lignin content increases and water content decreases. Trees can be divided into deciduous and coniferous species. Deciduous trees have a lower resin content and lignin when compared to conifers, but the heating value per m^3 is significantly higher for deciduous trees [12]. Table 2 shows the calorific value of wet wood in relation to dry wood.

Table 2

Calorific values of different types of wood [9]

Wood calorific value [GJ/m³]						
Moisture [%]	beech, oak	birch	willow	larch	pine, alder	spruce
0	10.83	9.69	6.65	8.74	7.98	7.60
15	10.59	9.47	6.50	8.55	7.80	7.43
20	10.49	9.38	6.44	8.46	7.73	7.36
25	10.37	9.28	6.37	8.37	7.64	7.28
30	10.24	9.17	6.29	8.27	7.55	7.19
35	10.09	9.03	6.20	8.15	7.44	7.08
40	9.92	9.87	6.09	8.00	7.31	6.96
45	9.71	8.69	5.96	7.84	7.16	6.81
50	9.46	8.47	5.81	7.64	6.97	6.64
55	9.16	8.19	5.62	7.39	6.75	6.43
60	8.78	7.85	5.39	7.08	6.47	6.16

A clear relationship between the calorific value of wood biomass and the humidity can be noted (Tab. 1 and 2). It justifies the initial drying of biomass before its further energetic use.

3. Research test

The drying process is aimed to reduce the moisture content of dried material by contact with gas and due to this operation the calorific value of wood is improved. This process is an important step occurring in most industries. Drying in a fluidized apparatus is an effective method. The general principle of this method is based on passing hot air (gas) through a bed of material on the perforated barrier. This barrier is called the gas distributor or fluidization barrier. As a result of the air flowing through the dried material from bottom to top the material is introduced into a fluidized state [5, 13, 14].

The biomass used in the research was derived from periodic cutting (plant care), distinguishing between the species of cut trees and sawmill waste. The sample results are presented on the example of birch chips.

Table 3

Properties of birch chips (solid biofuels) [8, 11]

Density (dry) [kg/m³]	Bulk density [kg/m³]	Equivalent diameter [mm]	Shape factor	Sphericity	Porosity
610	317.2	7.7	3.1	0.32	0.48

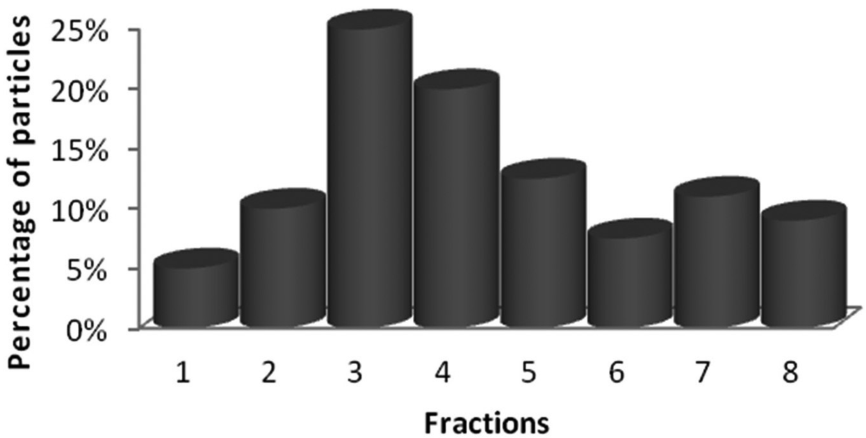

Fig. 2. Sieve analysis of birch wood chips: 1 – pieces 6.4–6.7 mm, 2 – pieces 7.1–7.6 mm, 3 – pieces 7.7–8.1 mm, 4 – pieces 8.3–8.5 mm, 5 – pieces 8.6–9.0 mm, 6 – pieces 9.1–9.6 mm, 7 – pieces 9.7–10.0 mm, 8 – pieces 10.3–10.8 mm

Rys. 2. Analiza sitowa zrębków brzozy: 1 – frakcja 6,4–6,7 mm, 2 – frakcja 7,1–7,6 mm, 3 – frakcja 7,7–8,1 mm, 4 – frakcja 8,3–8,5 mm, 5 – frakcja 8,6–9,0 mm, 6 – frakcja 9,1–9,6 mm, 7 – frakcja 9,7–10,0 mm, 8 – frakcja 10,3–10,8 mm

Research materials varied in granulation (shape, size) and quality (sawmill waste). Figure 2 shows the results of sieve analysis performed on random samples of the research material (correlation of % share and equivalent diameter), birch wood chips obtained from plant care cuttings. The structure of the fluidized load and the nature of its changes are important for proper organization of fragmented biomass drying, particularly wood chips. Fluidization of these materials in a classic apparatus is almost impossible. Effective fluidization should ensure getting an easy control over the fluidized layer, high energetic efficiency by the effective use of gas, minimization of dust amounts and disturbances of the process.

To ensure the effective fluidization of the analyzed material the original gas distributor was used [15], which enabled to obtain a layer with the properties intermediate between a classical fluidized bed, spouted bed and vortex bed (Fig. 3). The possibility of obtaining the fluidized bed for all of the test materials was confirmed. The applied distributor prevents classic disturbances such as pistoning or channeling, and the amount of dust minimized.

It was found during the research that technical benefits of using the proposed design solution are the following: the intensification of fragmented biomass drying process, reduction of dust (up to 4% of the bed mass in terms of dry material) with a simultaneous possibility of increasing the fluidizing agent flow rate, uniformity of drying, and high universality.

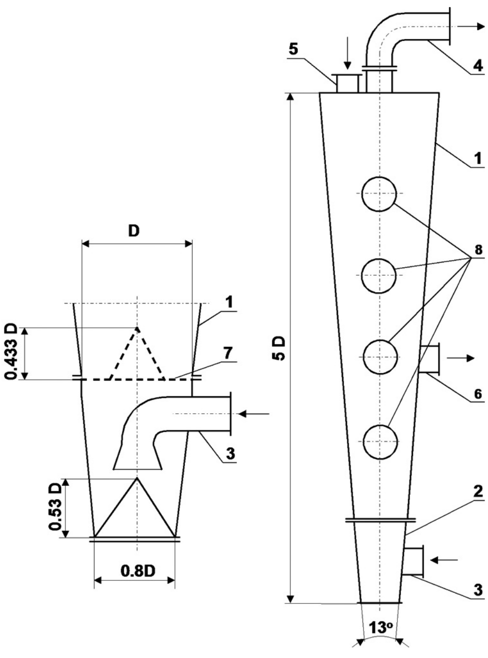

Fig. 3. Fluidized dryer for fragmented biomass: 1 – drying chamber, 2 – gas distributor chamber, 3 – air supply, 4 – air exhaust, 5 – supply of moist material, 6 – discharge of dried material, 7 – grate, 8 – speculums

Rys. 3. Suszarka fluidyzacyjna do suszenia rozdrobnionej biomasy: 1 – komora suszenia, 2 – komora dystrybutora gazu, 3 – doprowadzenie powietrza, 4 – odprowadzenie powietrza, 5 – doprowadzenie materiału wilgotnego, 6 – odprowadzenie materiału wysuszonego, 7 – ruszt, 8 – wzierniki

4. Conclusions

The use of drying can increase the calorific value of wood biomass, which makes the combustion process more advantageous in terms of energy, economics and environment.

There is a possibility of drying the fragmented wood biomass in the fluidized bed. The proposed original design solution for the fluidization apparatus allows effective fluidization of the fragmented wood biomass.

The use of biomass in Poland will grow due to the directive accepted by the European Union on renewable energy share in overall energy production in all member countries (for Poland 7.5% in 2010, 14% in 2020) [16].

Research and tests are being continued and include a wide range of process parameters and types of dried materials, assuming cost minimization.

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